

Lighting up disease-carrying mosquitoes

Sandia’s QUASR enables speedy, accurate detection of West Nile and other viruses

By Patti Koning

Mosquitoes are deadly efficient at spreading disease. Despite vaccines and efforts to eradicate the pesky insects, they continue to infect humans with feared diseases like Zika virus, malaria, and West Nile virus.

Gaining the upper hand on mosquitoes requires speed. Their life cycle is typically two weeks or less and they need only warm weather and standing water to breed.

See also . . .



Sandia, UCLA develop screening libraries to discover drug targets for viral infections.

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Chemical engineer Robert Meagher (8621) has developed a simple technique for simultaneously detecting RNA from West Nile and chikungunya virus in samples from mosquitoes. He is now working to add the ability to screen for Zika virus.

“Our ultimate goal is to develop an autonomous device to passively monitor for mosquito-borne diseases,” Robert says. “But first you need an assay that is more robust than the gold standard in a laboratory and that has a very low false-positive rate.”

Brighter than the sun

Robert and Sandia colleagues Yooli Light (8633), Chung-Yan Koh, and postdoctoral researcher Cameron Ball (both 8621) describe the technique in a paper published online in *Analytical Chemistry*, “Quenching of unincorporated amplification signal reporters (QUASR) in RT-LAMP enables bright, single-step, closed-tube and multiplexed detection of RNA viruses.”

They explored reverse-transcription, loop-mediated isothermal amplification (RT-LAMP), an isothermal nucleic acid amplification technique used instead of the more common polymerase chain reaction (PCR) for low-cost or point-of-care diagnostics for infectious diseases.

(Continued on page 5)



RED MEANS A DISEASE is present to Sandia researchers Cameron Ball and Robert Meagher as they test their QUASR, quenching of unincorporated amplification signal reporters, a technique to detect the presence of malaria and viruses like West Nile. Simple enough for field labs and handheld devices, QUASR’s positive signal is 10 times brighter than a negative signal.

(Photo by Dino Vournas)



Rooftop solar

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Bumper crop of partnerships

Sandia CRADA boom sets records, forges ties

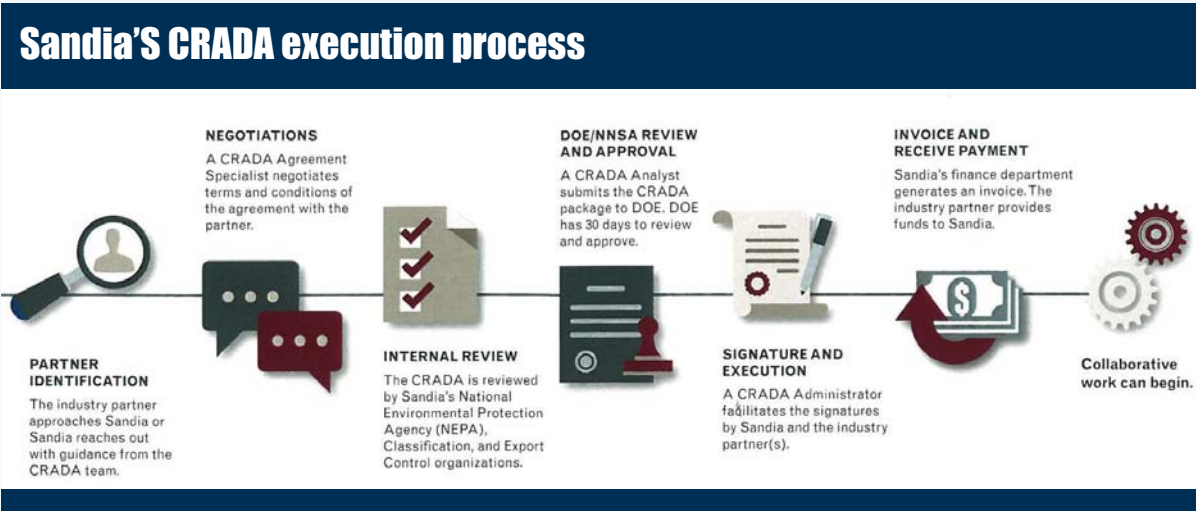
By Nancy Salem



Sandia entered into a vast array of new Cooperative Research and Development Agreements (CRADA) between fiscal years 2013 and 2015, bringing dozens of new partners to the Labs.

“This is a great mechanism for getting Sandia technology into the private sector,” says CRADA specialist Jason Martinez (10575). “We develop cutting-edge technology and capabilities with underlying science that is phenomenal. The CRADA is a vehicle to take that work and benefit the US economy.”

A CRADA is an agreement between a government agency and a private company or university — or at least one non-federal entity — to work together on research and development. Sandia signed 133 CRADAs during the past three fiscal years; 82 were new and 51 were amendments adding tasks or funding to existing agreements. The actual contract value to Sandia, which includes in-kind and government dollars, was more than \$105 million.



For more info on Sandia’s CRADA program visit sandia.gov/working_with_sandia/agreements/crada

Sandia has active CRADAs with 65 partners ranging from small businesses to nonprofits to industry giants. The Labs recently executed one with a university for the first time in 15 years.

“FY 13, 14, and 15 were all record years for CRADAs, and FY16 is on track to be another one, in numbers and in value,” Jason says. “It could be significant.” About 15 have


been signed so far in FY16, one with the second-largest value on initial execution in Labs history.

Andy McIlroy, director of Research Strategy & Partnerships Dept. 1900 and deputy chief technology officer, says CRADAs serve Sandia’s national security mission by broadening the impact of the Labs’ work through interactions with companies and other entities. “The partnerships also enrich the Labs with more perspectives,” he says.

A cornucopia of companies

There has been no single reason for the boom, Jason

(Continued on page 6)



Directed energy

Sandia is playing a key role on a team developing a missile that uses high-powered microwaves to knock out enemy electronics. The project has received \$10 million from the Air Force to prepare the weapon for the battlefield. See page 5.

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Light Electrical Lab

Improved lab has more floor space and new equipment to take its work to the next level. The lab handles tiny electronics components, including custom-built components that must survive in extreme environments. See page 4.

That’s that

The emergence of autonomous machines as implements of war has become a hot-button topic in defense circles. What we’re talking about here are machines that are able to act untethered from their human controllers and make “decisions” on their own based on parameters programmed into them and the rules of engagement they’re programmed to follow.

To be sure, at all levels of the nation’s national security complex, the subject has been of interest for years, if not decades. But with a convergence of technologies moving the concept from the realm of science fiction to imminent reality, the topic has increasingly come out of the shadows, most recently in a live-streamed “conversation” sponsored by *The Washington Post* and hosted by the *Post*’s highly regarded foreign affairs columnist, David Ignatius.

In the conversation, Deputy Defense Secretary Robert Work said that “inexorably” the US over the next few years will deploy autonomous machines in what he called the battle network. But those machines will operate within very narrow, tightly defined spaces. They will emphatically not have the capability to make lethal, life/death decisions. Rather, their capabilities will be akin to the autonomous parking feature in your car.

“You push the ‘I believe’ button and you believe your car will autonomously park itself. We will have certain things like that in our battle network. But we will not delegate lethal authority for a machine to make a decision.”

That is because a key aspect of America’s military prowess, Work said, has always been the independent judgment of our warfighters.

“One of our best advantages is that we have young men and women who have grown up in what I call the ‘i-world,’ in a democracy. We value the innovative spirit; we value initiative. We are totally okay with irreverence, where they kind of mock authority, where they say, ‘Oh that’s dumb, let’s do it this way.’

“We totally like that because we think that will make our network more vibrant and dynamic. But we’re up against competitors . . . who would like to take out that creative spirit and just make sure that everyone follows the orders of the person on the top. So we might be going up against a competitor who is more willing to delegate [lethal] authority to machines than we are. As that competition unfolds we’ll have to make decisions about how we can best compete. It’s not something we’ve fully figured out but we’ve spent a lot of time thinking about it.”

In the fascinating 45-minute conversation conducted before a live audience (see it here: <https://www.washingtonpost.com/news/securing-tomorrow/>), Work painted a picture of a world where the complexity of challenges in the national security sphere are so daunting that they demand the nation’s best brainpower to conceive of and develop the answers to new threats, to remain leaders rather than what Work called “fast followers.”

On a different note, Work said something that I found interesting regarding how sensitive information is shared with the public – and why.

“We will reveal for deterrence and conceal for warfighting advantage. There are a lot of things in the budget that we don’t talk about because we want to reserve that in case, God forbid, deterrence fails and we do come to a collision of arms. But we will reveal things that we hope will deter.”

Let me change strides here for a moment. In our FY16-FY20 Strategic Plan, we put forward as our vision this statement:

On behalf of our nation, we anticipate and solve the most challenging problems that threaten security in the 21st century.
When we achieve this vision, we are widely recognized as a national leader in preventing technological surprise, anticipating threats, and providing innovative, science-based systems engineering solutions to our nation’s most challenging security problems.

In thinking about Work’s comments in the context of our vision, it occurred to me that Sandia may be the indispensable lab. With the nation’s smartest people tackling the toughest problems, with an unparalleled suite of capabilities housed under one roof (so to speak), and with a robust and growing network of strategic partners, we are uniquely positioned to help ensure American leadership and global stability in a rapidly evolving world. Now *that’s* something to get up and come to work for every day.

See you next time.
– Bill Murphy (MS 1468, 505-845-0845, wtmurph@sandia.gov)

Hydrogen Risk Assessment Models toolkit now available



By Michael Padilla

Sandia’s Hydrogen Risk Assessment Models (HyRAM), a first-ever software toolkit to assess the safety of hydrogen fueling and storage infrastructure, is now available at hyram.sandia.gov.

Sandia will introduce the toolkit, which integrates hydrogen safety data and methods, during a webinar on April 26. Register at <http://energy.gov/eere/fuelcells/webinars>.

“HyRAM provides a common platform for individuals conducting quantitative risk assessment and consequence analysis for hydrogen systems,” says Katrina Groth (6231). “Sandia has done extensive research to ensure that the toolkit will provide standards development and code development organizations with state-of-the-art, validated science and engineering models.”

Development of HyRAM began several years ago through the Office of Energy Efficiency and Renewable Energy’s (EERE) Fuel Cell Technologies Office, and it has been tested and demonstrated to a variety of stakeholders. The HyRAM toolkit addresses key barriers to hydrogen infrastructure deployment, including limited access to safety data, lack of models describing hydrogen behavior, and the need for technical data for revising standards. Developing hydrogen codes and standards can be challenging because the relevant models and technical data span multiple scientific and engineering disciplines.

The HyRAM toolkit integrates state-of-the-art models, methods, and data used to inform fire codes to provide a common platform for assessing hydrogen safety. With the HyRAM platform, this information becomes accessible to engineers, code officials, and risk analysts to quantify accident scenarios, predict physical effects, and characterize the impact of hydrogen hazards on humans and structures.

HyRAM provides the scientific basis and documented methodology that ensure code requirements are consistent and defensible. In addition, HyRAM reduces industry burden and allows hydrogen safety experts to obtain safety insights using a common set of tools. HyRAM formalizes the tools and methods that were employed in recent updates to building codes from the National Fire Protection Association (NFPA). This risk-informed approach in the revised code has been shown to significantly increase available locations for deployment of hydrogen refueling infrastructure in the state of California, as the state develops a network of more than 100 hydrogen-refueling stations.

Sandia’s Hydrogen and Fuel Cell program provides the science and engineering to accelerate the deployment of clean and efficient hydrogen and fuel cell technologies.

The program leverages a diverse set of assets across Sandia, including expertise in grid modernization, renewable energy production, and materials science.

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Bill Murphy, Editor 505/845-0845

Randy Montoya, Photographer 505/844-5605

Patti Koning, California site contact 925/294-4911

Michael Lanigan, Production 505/844-2297

Contributors: Michelle Fleming (Ads, Milepost photos, 844-4902), Neal Singer (845-7078), Stephanie Holinka (284-9227), Darrick Hurst (844-8009), Heather Clark (844-3511), Sue Holmes (844-6362), Nancy Salem (844-2739), Valerie Larkin (284-7879), Lindsey Kibler (844-7988), Tim Deshler (844-2502), Rebecca Brock (844-7772), Mollie Rappe (844-8220), Michael Padilla (925-294-2447), Valerie Smith, manager (844-6167)

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Sandia, UCLA develop screening libraries to discover drug targets for viral infections

Project based on CRISPR genome-editing technology

By Michael Padilla

As headlines highlight the threat of viruses like Ebola and Zika, researchers at Sandia and the University of California Los Angeles (UCLA) have teamed up to discover and uncover the viral mechanisms of infection by creating screening libraries based on CRISPR (clustered regularly interspaced short palindromic repeats) genome-editing technology.

“CRISPR technology allows researchers to easily knock out or remove specific genes from a host cell,” says Oscar Negrete (8621), who is spearheading the project for Sandia to develop the libraries that will be used to screen Zika and many other viruses. “CRISPR libraries are built to target large sets of genes simultaneously.”

Using these libraries, researchers can rapidly understand how removal of these genes affects virus infection. By discovering host genes essential for infection through CRISPR library screening, researchers can begin to design anti-viral treatments using those identified gene or gene products as targets.

CRADA is first ever with UCLA

Oscar is co-leading the project with Robert Damoiseaux, director of the Molecular Screening Shared Resource at UCLA. Sandia researchers Joe Schoeniger (8633), Sara Bird (8621), and Edwin Saada (8633) also are working on the year-long project, “Development of Arrayed CRISPR-based Libraries for Functional Genomics Screening.” The work is part of the first-ever Cooperative Research and Development Agreement (CRADA) between Sandia and UCLA.

This work is conducted under Sandia’s Laboratory Directed Research and Development program, which invests in high-risk, potentially high-payoff science, technology, and engineering challenges with high potential to make a significant impact on national security.

“The purpose of our CRADA is using an alternative method of library assembly to produce arrayed CRISPR libraries at a fraction of the cost of standard methods,” Oscar says. “Instead of producing individual constructs one by one, which by standard methods are relatively expensive and labor-intensive, we will start out with a mixture of CRISPR constructs called a pooled library that is easy and inexpensive to produce, then separate or array the mixture into individual constructs using high-throughput robotic equipment. Using next-generation sequencing, we can then decode the constructs to build the arrayed formatted library.”

“Like a jar of jellybeans, a pooled CRISPR library is a complex mixture,” Oscar explains. “An arrayed library, on the other hand, is more like individually wrapped and labeled jellybeans. When you identify a particular CRISPR of interest from a pooled screen, you still have to run a deconvolution experiment to know what you have. In arrayed libraries, the CRISPR of interest is already labeled, therefore hit identification is much easier, quicker, and cheaper.”

Researchers aim to produce a genome-scale arrayed CRISPR library, but will initially focus on building a sub-library that targets the membrane proteins involved in cell communication and that act as receptors for pathogen entry.

Arrayed libraries accelerate discovery

CRISPR evolved in nature as a bacterial defense system and now serves as the basis of a powerful genome editing technology. Oscar says CRISPR has created a biotechnology revolution similar to the discovery of the polymerase chain reaction (PCR) technique used to make millions of copies of a segment of DNA.

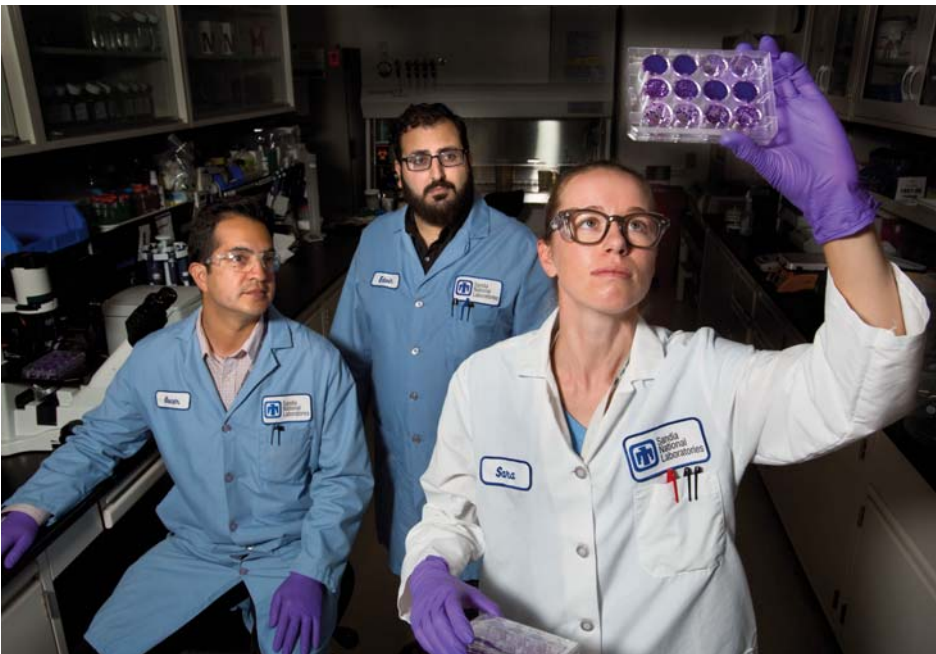
“This technology is moving medicine in a whole new direction where researchers are trying to cure any disease that has a genetic component,” Oscar says. “With CRISPR, it is theoretically possible to modify any genome including the human genome. It could one day hold the cure to any number of genetic diseases.”

This CRADA effort will develop efficient routes toward arrayed libraries using high-throughput screening and sequencing methods.

“As a research tool, CRISPR is an ideal genome engineering system for functional genomic screening,” Oscar says. “CRISPR-based genetic screens are particularly useful for studying diseases or phenotypes for which the underlying genetic cause is not known.”

Before CRISPR, scientists relied heavily on RNA interference-based genetic screens, which are prone to off-target effects and may result in false negatives due to incomplete knock-down of target genes. The CRISPR system can make highly specific, permanent genetic modifications in target genes and already has been used to screen for novel genes that regulate disease-related phenotypes.

The most common method for conducting genome-wide screens using CRISPR involves the use of “pooled” libraries. A pooled CRISPR library is a complex mixture of thousands of unique sequences, which is then delivered to a single group of cells in bulk for screening disease phenotypes. Since the libraries are delivered in bulk, analyses of phenotypes are limited. By contrast, arrayed CRISPR libraries are generated



CRISPR CRADA – Sandia researchers, from left, Oscar Negrete (8621), Edwin Saada (8633), and Sara Bird (8621) check out a CRISPR library preparation. The work is part of the first-ever Cooperative Research and Development Agreement between Sandia and UCLA.

(Photo by Dino Vournas)

in multiwell plates, where each well contains a vector preparation targeting an individual gene. Using this type of library, it is possible to explore complex phenotypes arising from a vast number of distinct cell perturbations. In addition, arrayed libraries provide access to rapid secondary follow-up screens.

Ready-to-use libraries

Access to screening of this novel CRISPR library will be made available to a wider scientific audience on a case-by-case basis. Sandia also plans to use the libraries for screening of viral mechanisms and drug target discovery.

The Molecular Screening Shared Resource (MSSR) offers a comprehensive range of high throughput screening services including chemical genomics, functional genomics and drug discovery. The MSSR is an open environment and welcomes academic investigators from UCLA and from all over the globe.

“This is just the beginning for the applications of this type of technology,” Oscar says. “If we can make an impact on Ebola and Zika, then we have accomplished our goal.”



Sandia inks pact with Fire and Rescue Training Authority



MARIANNE WALCK, vice president of Sandia’s California site and the energy and climate program and Ruben Grijalva, executive director of CFRTA, which includes the Governor’s Office of Emergency Services, Sacramento Metropolitan Fire District, and Sacramento Fire Department, sign the agreement. (Photo by Dino Vournas)

By Michael Padilla

Sandia and the California Fire and Rescue Training Authority (CFRTA) have signed a memorandum of agreement to develop new concepts and capabilities for emergency planning, exercise, and response.

The agreement was signed by Marianne Walck, vice president of Sandia’s California site and the energy and climate program, and by Ruben Grijalva, executive director of CFRTA, which includes the Governor’s Office of Emergency Services, Sacramento Metropolitan Fire District, and Sacramento Fire Department.

“The strong relationship between Sandia and the CFRTA has yielded many benefits,” Marianne says. “Sandia has gained operational partners through which we are transitioning technology to emergency managers and first responders and CFRTA has gained access to technologies that can enhance preparedness across the state. This is a perfect opportunity for Sandia to deploy technology in the field to test operational concepts, evaluate readiness and refine technology requirements.”

Grijalva says the agreement between Sandia and CFRTA provides a framework of cooperation in a variety of vital areas of emergency response planning and training at the California Exercise Simulation Center (CESC) in Mather.

The CESC is an exercise and research facility operated by the CFRTA that helps prepare first responders and incident

commanders by simulating catastrophic and complex emergency scenarios at low cost. The CESC serves as a satellite facility of the Federal Emergency Management Agency’s National Exercise Simulation Center network, supporting the center’s mission of enhancing regional preparedness.

“The work provided by Sandia will help emergency responders be better prepared to respond to large-scale, human-caused and natural disasters,” Grijalva says. “This new partnership will allow the CESC to be used as a testbed for Sandia-developed technologies.”

The agreement builds on a recent \$50,000 grant from the state of California to Sandia to build three emergency response scenarios for the state and the CFRTA on wildfire, chlorine tanker release, and radiological dispersal device (RDD). The nine-month project will begin next month.

To develop the scenarios, Sandia will link a set of models and data for California to simulate the spread of hazards from wildfires, toxic chemicals, and radiation. Based on predictions of areas that could be affected, the models will estimate potential impacts on population, infrastructure, and the economy. Once the basic scenario has been created, emergency managers can evaluate a wide range of possible outcomes by varying key scenario conditions, such as weather, size of a chemical spill, or response options. The scenarios will help emergency managers better prepare for a broader set of incidents.

Upgraded, expanded Light Electrical Lab provides Sandia with in-house expertise for tiny electronics



LAB EXPANSION — Maxine Norton, left, and Etta Tsosie (both 5346) work on electronics in a newly expanded section of the Light Electrical Lab. The now-completed upgrade doubled the

lab's floor space, making room for new equipment to take their work to the next level. The lab serves all Sandians. (Photo by Randy Montoya)

By Heather Clark • Photo by Randy Montoya

As an 8-year-old girl herding sheep on the Navajo Nation, Etta Tsosie (5346) found a discarded radio and fixed it by installing a scavenged diode.

“My first soldering iron was a butter knife,” says Etta, remembering how she managed to insert the diode.

From that auspicious beginning, Etta studied electronics at TVI (now CNM), worked in electronics before joining Sandia as a custodian, and then assembled parts for neutron generators. Eventually, she took a job in Sandia Center 5300’s Light Electrical Lab and, with electronics technician Maxine Norton (5346), has advocated for its now-completed upgrade and expansion.

“It was so crammed in here that we couldn’t use the machinery,” Etta recalls.

Space is no longer an issue in Bldg. 891, Lab 1071B. The improved lab has about double the floor space and new equipment to take its work to the next level. The lab handles tiny, even microscopic, electronics components, including custom-built components that must survive in extreme environments, like outer space.

The new equipment includes:

- an Ersa PL 650 Rework System that can penetrate thicker circuit boards and is used to inspect electronics or fix them.
- a Verifier HR130 X-ray machine used to look for moisture, air pockets as small as a speck of dust, or areas where solder is missing. Such anomalies can cause the board to malfunction, Maxine says.
- a Cascade TEK Forced-Air Oven used to bake moisture out of components.
- a Lumenera Optic 2 Camera.

The two technologists say the upgrades can save scientists and engineers time and money.

Etta, who began her career with the Labs’ custodial staff in 1986, has worked in the Light Electrical Lab since 2000 and has seen her skills help with many successes, including work on the laser dynamic range imager for NASA’s space shuttle program and robotics.

When a printed circuit board on Sandia’s Miniature Autonomous Robotic Vehicles was short-circuiting as a certain part was attached, Etta says she found out why. She discovered an exposed vertical interconnect access, or via, an electrical connection between layers in an electronic circuit. She covered the exposed electronics and soldered the component on top to

fix the problem.

Years later, she says, she was delighted to hear the Smithsonian Institution requested the robots for its permanent collection.

A quick turn-around

Each year, the lab serves an average of 90 customers from different organizations at Sandia, Etta says, adding the lab is open to all organizations at the Labs that need its help.

Maxine, who worked as an OAA for many years, switched to the technical side by joining the Light Electrical Lab and is currently studying for her associate’s degree in systems technology.

Etta, who is planning to retire after 30 years at Sandia, is mentoring Maxine in her new role. Both technologists have Class 3, or high quality level, certifications.

The jobs the technologists can perform include visual inspections of populated printed circuit boards and printed wiring boards, adding components to both types of boards, installing or replacing ball grid arrays (BGAs), X-rays, modifications of boards or parts, repairs, conformal coating, cleaning boards, cleaning during operations, and inspections.

Anthony Ernest (5332), a microwave and sensor engineer, says he relies heavily on the lab’s expertise when validating prototypes for defense projects, working with BGAs, designing components to survive extreme environments, and other tasks. Often he works side-by-side with Etta and Maxine to troubleshoot, and the lab has a quick turn-around, he says.

“Their expertise definitely enables our group to deliver,” Anthony says. “For many flight tests we’ve had, they’ve been instrumental to our success.”

The best of both worlds

Both women enjoy seeing programs achieve success due to their work and they are happy they could pursue careers as technologists.

“I have the best of both worlds: to be in the program at school and learn the technical jargon and to be hands-on at my job,” Maxine said.

When Maxine was researching to become a technologist, she remembers Etta using the analogy of having experience silversmithing. Etta thought some Native Americans are naturally good at soldering because of that. “To me, it’s an art, a craft that I do,” Etta says. “Everyone always asks me whether I love my job, and I say, ‘Yes, I love my job. This is what I always wanted to do.’”

Directed-energy tech receives funding to field weapon for the military

By Heather Clark

A team developing a missile that uses high-powered microwaves (HPM) to knock out enemy electronics received \$10 million from the Air Force to prepare the weapon for the battlefield.

Sandia has worked on the HPM technology that enabled the Counter-Electronics High-Power Microwave Advanced Missile Project, or CHAMP, for more than two decades, says Jeff Alexander, manager of Directed Energy Special Applications Dept. 5443.

“HPM provides a game-changing, scalable, and non-lethal option for the warfighter,” Jeff says. “The technology will save lives by more closely targeting and crippling an enemy’s electronics systems without hurting civilians or even the building containing the targeted electronics.”

Sen. Martin Heinrich, D-N.M., announced the \$10 million effort that includes a \$4.8 million contract for Raytheon Ktech in the Sandia Science & Technology Park; \$3.8 million for the Air Force Research Laboratory (AFRL); and \$1.4 million that Sandia received from the Air Force to refurbish and enhance the CHAMP payload. The work is being done under an existing strategic partnership with AFRL.

“This contract will allow Raytheon Ketch here in Albuquerque, as well as Sandia and AFRL, to take this to the next level,” Heinrich said. “I truly believe that directed-energy weapons will play a critical role in future weapons systems across the military. Directed-energy technology will provide the military with a qualitative advantage over our adversaries.”

CHAMP team members

The 2013 ERA Team for CHAMP’s currently active employees include: Fernando Bitsie and Eric Stasiunas (both 1521); Burke Lloyd Kernen, Enrico Quintana, and Kyle Thompson (all 1529); Joshua Usher (1647); Guillermo Loubriel (1755, formerly 5443); Grace Santillanes (2633); David Joseph Gurule (2557); Jason Shelton (2728); Steven Dron (5426); Jeff Alexander, Phillip D. Coleman, Paul Primm, and Jeffery T. Williams (all 5443); and Larry Lucero (5445).



AT AN EVENT WHERE HE ANNOUNCED A \$10 million effort to further develop directed-energy technology for the nation’s military, Sen. Martin Heinrich, third from right, is joined by, from left, Center 5400 Director David Plummer; Kelly Hammett, chief engineer, Directed Energy Directorate, Air Force Research Laboratory; Heinrich; Robert Fitzpatrick, VP for Business Development, Raytheon Missile Systems; and Steven Downie, site director, Raytheon Albuquerque. (Photo by Linda von Boetticher)

The refurbishment and enhancement effort is the next step for CHAMP technologies, following a 2012 flight test.

Directed-energy weapons emit highly focused energy — examples are HPM and lasers — to destroy a target.

For CHAMP, the Labs has provided pulsed-power engineering, high energy density physics design and modeling, and weaponization of the technology’s hardware and components, said David Plummer, director of Integrated Military Systems Center 5400.

“AFRL and Sandia have worked together for more than 20

years. We think our partnership is a model for interagency collaboration, in this case between Defense and Energy,” David said.

If the partners are successful in fielding CHAMP, the work could set the stage to develop a substantial funding stream for directed-energy work in New Mexico, Heinrich said.

In addition to working with national firms, Sandia’s directed-energy work also has benefited laboratories and businesses in the state, David said. “New Mexico is poised to play a significant role in the future of this technology,” he said.

QUASR

(Continued from page 1)

However, in its usual form, RT-LAMP requires too many manipulations or elaborate instrumentation to be suitable for field use or an autonomous device.

RT-LAMP relies on primers, DNA fragment sequences, that bind to a target — the RNA of the virus of interest — and then generate a large amount of DNA. By fluorescently labeling the primer, the new DNA glows as it is produced. If the primer doesn’t find the viral RNA, there is no glow.

The Sandia researchers added a different DNA fragment sequence called a quench probe that complements a short stretch of primer. As the reaction takes place, the quench probe suppresses any unincorporated primer. This amplifies the positive signal up to 10 times brighter than a negative signal. Because the signal is so bright, QUASR can screen up to three different targets simultaneously, saving time and money.

“We didn’t expect a signal that bright, so we came up with the name QUASR, inspired by quasars, the extremely luminous celestial objects that can be a trillion times brighter than the sun,” Robert says.

QUASR is simple enough to be used in a field laboratory. The Sandia team is working to incorporate QUASR into a handheld device.

Vector-control districts stand to benefit greatly from QUASR. Such districts are typically the units of public health agencies that monitor and control disease-carrying insects locally.

QUASR enables rapid response

Currently, detecting disease-carrying mosquitoes is a complex and lengthy process. A field worker in a vector control district collects and prepares mosquito samples, which are then sent to a lab for testing using sophisticated PCR techniques.

Using QUASR, either in a portable microfluidic device or simple field laboratory, a user can get a definitive yes or no result in about half an hour. More details like the amount of viral RNA present in the sample would still require laboratory PCR.

“This would allow those in the field to make quick deci-

QUASR primer and complementary quenching probe

5' dye 3' quencher $T_m < T_{Rxn}$

Negative = Dark **Positive = Bright**

Multiplexed detection of West Nile virus and Chikungunya virus

+	+	-	-
+	-	+	-

QUASR IMPROVES THE SIGNAL obtained from the traditional DNA amplification technique known as LAMP, which can be coupled with a reverse transcriptase to amplify RNA targets. QUASR attaches a dye to a LAMP primer of interest, causing amplified DNA to fluoresce brightly enough to be read by the human eye. A complementary quench probe attaches to any unincorporated primer after the reaction cools, making negative reactions dark. The difference between positive and negative reactions is unambiguous enough to enable simultaneous detection of multiple viruses.

sions on mosquito abatement that can prevent the spread of disease,” Robert says.

QUASR also can be adapted to screen people for diseases such as the Zika virus or Ebola virus. This is a constantly changing landscape; a year ago, few people had even heard of Zika virus, which the World Health Organization recently declared an international health emergency.

“Conceptually, it’s not difficult to adapt the assay for a different virus,” says Robert. “There is some trial and error involved in refinement as you are dealing with a different virus and human sample.”

Robert recently received a National Institutes of Health (NIH) grant to develop a field-deployable assay for differential diagnosis of malaria and viral febrile illnesses including Ebola. The University of Texas Medical Branch at Galveston is a partner in the grant.

Because malaria and Ebola have similar symptoms — fever, chills, headache, diarrhea, and vomiting — health officials worry that patients with malaria are being sent to Ebola quarantine wards.

“A point-of-care device that can quickly discriminate Ebola from malaria in a blood sample would prevent dan-

gerous misdiagnoses,” says Robert.

Lassa, dengue, and other febrile illnesses are also targets for the NIH project.

A bright future

Robert and his team set out to tackle the problem of false positives. “Even a marginal false positive rate would defeat the purpose of an autonomous monitoring device,” he says. “The signal amplification, the amazing brightness of the positive response, was not a goal but certainly a welcome result.”

While the human eye can only effectively discriminate three distinct colors, the team is developing imaging technology that could enable simultaneous screening of even more targets.

“I’m very excited about what this technique can do for field workers,” Robert says. “The ability to make fast decisions about where to direct mosquito abatement resources or how to triage patients will help us stay ahead of mosquito-borne disease outbreaks.”

The work was funded by Sandia’s Laboratory Directed Research & Development program.

Two inspirational Sandia women in ceramic and glass engineering

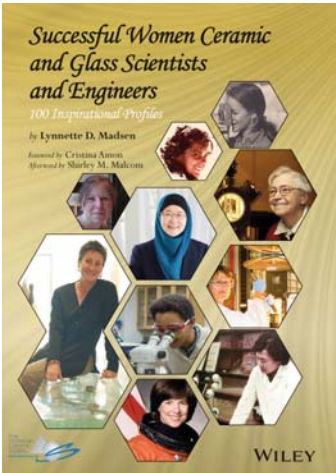
By Mollie Rappe

Science, technology, engineering, and math disciplines have an underrepresentation problem. The reasons for this underrepresentation are complex, including difficulties attracting and retaining women and minorities, sometimes referred to as the “leaky pipeline.” In engineering disciplines, women have received approximately 20 percent of bachelor’s and master’s degrees since 2000, yet women make up only 11 percent of practicing engineers.



JULIA PHILLIPS

Lynnette Madsen, program director for ceramics at the National Science Foundation, recently published a book highlighting the careers and lives of 100 diverse and successful women in ceramic and glass science and engineering. Her goal was to attract young women into the field and encourage them to stay. Two of the women featured in this tome have strong ties to Sandia.



TINA NENOFF

Julia Phillips, now retired, was involved in many leadership positions at Sandia for almost 20 years. Julia’s proudest career moment was guiding the research strategy for the Labs. From February 2013 to October 2014 she served as an acting vice president and chief technology officer.

“It is an honor to be included in the book, in the company of so many accomplished women scientists and engineers. I hope that readers will see that there are as many paths to success in both career and personal fulfillment for women in science and engineering as there are women to make them. The ‘words of wisdom’ should be valuable for all early career researchers,” said Julia.

Tina Nenoff (1100), a distinguished materials scientist, has worked at Sandia since 1993. Tina’s proudest career moment was enabling Sandia’s crystalline silicotitanate (CST) molecular sieves for the removal of radiological cesium from seawater at the Fukushima Dai-ichi Nuclear Power Plant.

Tina also was honored by her inclusion in the book. “Many of the women featured in the book are my mentors like Julia Phillips, Alexandra Navrotsky, and Carol Jantzen. Many are my friends and peers like Jackie Ying and Claire Gray. I hope this book reminds, or possibly exposes for the first time, the reader to the amazing research in science and engineering that has been happening over the years.”

Sandia’s CRADA boom

Continued from page 1



R&D PARTNER — William Kurtz, left, president of IR Dynamics LLC of Santa Fe, is working with Sandia’s Nelson Bell (1815) through a Cooperative Research and Development Agreement. IR Dynamics is developing thermochromic materials to control infrared transmission. CRADAs fall into a variety of technology areas and divisions within different PMUs at the Labs.

(Photo by Norman Johnson)

says. “It’s like farming. Sometimes there’s a bumper crop that you can’t attribute to one particular thing like the soil or the weather,” he says. “There is a cornucopia of companies and organizations that want to work with us. We’ve seen a bumper crop of CRADAs.”

A standard CRADA covers a single project in one technical area in a fixed amount of time, and an umbrella covers multiple projects and technologies over a span of time. “An umbrella is more strategic, offering the dynamic ability to place different project and task statements in different areas,” Jason says. “One of our partners has more than 100 project and task statements over different organizations and PMUs.”

the Laboratories to augment awareness and let people know this can be a vehicle to supplement finite resources,” Jason says. “The word is getting out internally and externally. We’re making it easier on both sides.”

Sandia created an external website devoted to CRADAs. “Someone who has never heard of a Federally Funded Research and Development Center or a CRADA can visit and ascertain what the steps are,” Jason says.

Members of the technical staff can seek industrial or university partners through ads on FedBizOpps, the database of federal government contracting opportunities, placed by the CRADA department. The ads also will appear on the Sandia CRADA website.

Sandian named Fellow of Society of Industrial and Applied Mathematics

By Sue Major Holmes

Sandia senior scientist Cynthia Phillips (1400) has been named a 2016 Fellow of the Society of Industrial and Applied Mathematics (SIAM) for her contributions to the theory and applications of combinatorial optimization.

SIAM, which announced 30 Fellows March 31, says they were nominated for their exemplary research and outstanding service to the community. They will be recognized for their achievements at an awards ceremony during the SIAM Annual Meeting July 11-15 in Boston. Cindy is one of only two Fellows named this year from national laboratories.

“I am honored and humbled to be on such a list with some of my professional heroes,” she says. “I am grateful to SIAM, my management, and my research colleagues, past and present. Sandia’s culture of valuing teamwork, enabling collaborations with academic researchers around the world, and emphasizing impact create an environment for pure and applied research in combinatorial optimization. I am just the representative of all the many excellent teams I have worked with throughout my career.”



CINDY PHILLIPS

Long-time active role in SIAM

Cindy is SIAM’s vice president for programs. She has held leadership positions in the SIAM Activity Group on Supercomputing and has been an invited plenary speaker at multiple SIAM conferences.

In January, she was one of two Sandia researchers selected as distinguished members of the Association for Computing Machinery, the world’s leading association of computing professionals.

Cindy, who works in Sandia’s Center for Computing Research, conducts research in combinatorial optimization, algorithm design and analysis, and parallel computation. She has applied these techniques to many areas including scheduling, network and infrastructure surety, integer programming, graph algorithms, computational biology, quantum computing, computer security, wireless network management, social network analysis/graph data mining, sensor placement, and co-design of algorithms for next-generation architectures. She received a bachelor’s degree in applied mathematics from Harvard University and a doctorate in computer science from the Massachusetts Institute of Technology.

SIAM, with headquarters in Philadelphia, is an international society of more than 14,000 individual, academic, and corporate members from 85 countries. The society helps build cooperation between mathematics and the worlds of science and technology to solve real-world problems through publications, conferences, and communities including chapters, sections, and activity groups.

The agreements are funded a variety of ways: A company pays to work with Sandia; the partners use DOE work authorization funds allocated to the Labs; or the funding comes from another federal agency or Laboratory Directed Research and Development, both of which fall into the in-kind category. CRADA contract values range from \$50,000 to multimillions.

Training and awareness

One reason for the boom is that Sandia’s CRADA department has been proactive, meeting with and training numerous technical groups at the Labs on the process and the opportunities. Training materials have been developed and the steps to doing a CRADA have been simplified. “We’re meeting with pretty much every technical line manager at

“CRADA partners benefit from 70 years and billions of dollars of taxpayer-funded research,” Jason says. “Sandia’s research can benefit the economy in important and impactful ways. It gives the CRADA partner the seed to commercialize a technology and develop a competitive advantage within their industry.”

Small is big



Sandia has Cooperative Research and Development Agreements (CRADA) with a variety of small companies. “There is a misperception that CRADAs are only for the big players,” says CRADA specialist Jason Martinez (10575). “We have a very active portfolio with small companies.”

Here are a few:

EyeTracking Inc.: Sandia is working with EyeTracking to produce algorithms, software, user interaction models, and user interfaces to advance state-of-the-art eye-movement data collection and analysis. Sandia’s research into human visual cognition with dynamic stimuli parallels the San Diego company’s recent advances in the analysis of complex interaction patterns. The CRADA will advance the collection and analysis of human visual perception and cognition with dynamic content.

IR Dynamics LLC: The Santa Fe company and Sandia’s Electronic, Optical, and Nano Materials Center are developing thermochromic materials for control of infrared transmission. They could be used as pigment additives for smart windows or pigment-based coatings in architecture, transportation, and clothing.

Red & White Fleet: Sandia and Red & White Fleet of San Francisco are doing a feasibility study on the design, construction, and operation of a multi-use, high-speed hydrogen fuel cell passenger boat and high-capacity multi-use hydrogen fueling station. The project aims to reduce maritime emissions to near zero, help develop and refine maritime hydrogen codes, and create a competitive alternative to current diesel boats. If the study shows a path forward, Sandia and Red & White Fleet will continue to collaborate.

SANDIA CLASSIFIED ADS

MISCELLANEOUS

ROYAL BAJA RUG, 100% wool, 8'2" x 11'9", Kashan pattern, ivory, blue, Belgium-made, mothproofed, like new. Upchurch, 797-0463.

UPRIGHT PIANO, Wurlitzer, \$2,000 OBO; antique grandfather clock, mahogany wood, \$1,600 OBO. Fisher, 293-2864.

WEDDING GOWN, Demetrios, tiara, veil, summer style, spaghetti straps, size 8, unaltered, never worn, \$200 OBO. Pollice, 505-363-5686.

BOSE WAVE RADIO II, graphite gray, \$250. Stikar, 884-4128.

INK JET CARTRIDGE, HP 920XL, black, new, \$20. Lierz, 293-2886.

ELECTRIC MOWER, Black & Decker, 4-hp, rarely used, \$50. Moreno, 294-4268.

MULTI-FAMILY GARAGE/MOVING SALE, furniture, household goods, etc. April 22-24, 8 a.m.-2 p.m., 341 Cardenas NE (San Pedro/Lomas area). Mares, 505-980-5438.

SOUND SYSTEM & EQUIPMENT, call for more details, \$2,500. Burrows, 505-869-6952.

WALL FOUNTAIN, Reflection Creek, new-in-box, LED, remote, antique bronze, green slate, 38" x 27" x 5", paid \$944, asking \$500. Fondren, 463-5572.

SAFE, Sentry H0100CG, fire-safe, waterproof, ETL verified fire protection & waterproof, privacy key lock, carrying handle, \$25. Brewster, 238-4704, ask for Julie.

POOL TABLE, Connelley Ventana, maple, 8-ft., w/sticks, \$750. McLeod, 238-2934, ask for Dan.

GARAGE SALE FUNDRAISER, April 22-23, 8 a.m.-2 p.m., AVON39 Breast Cancer Walk, 12404 Casa Grande Ave. Good, 505-259-9034.

TV, Sony, 45-in.; Denon AVR, HSU and NHT subs, \$200 ea., \$700/all; call for more info. Buksa, 505-285-4391.

TIRES/WHEELS SET, stock '12 Tacoma, \$400; Leupold scope, \$200; Sharp microwave, 1600-W, \$100; gravel, estimate/offer required. Valerio, 505-331-7242.

BEDROOM SET, oak, queen, slatted head & foot board, chest-of-drawers, dresser w/mirror, nightstand, excellent, \$700. Adams, 934-6294.

LAPTOP, Lenovo IdeaPad U410, i5, 14-in. HD screen, 8GB memory, 1TB disc drive, Win10, \$200. Sutherland, 345-1183.

SPARE TIRE CARRIER, Roadmaster motorhome, new, \$550. Gehrke, 263-7327.

REFRIGERATOR, Kenmore Elite, French door, bottom freezer, stainless steel, immaculate, perfect working condition, \$650 OBO. Green, 505-239-6914.

DUAL WHEEL GRINDER, w/stand, Craftsman, 1/6-hp, \$20. Reed, 821-7782.

TIRES, 4, Continental Control Contact Tour A/S, 205/55R16, 90% tread, excellent condition, \$350. Haslett, 505-866-5740.

DINING TABLE SET, 40" x 70", seats 6, 2 arm chairs, very good condition, photos available, \$150. Dai, 505-990-9116, ask for Steve.

CLASSICAL GUITAR, Martin Sigma, vintage, early 1970s, w/case, \$150. Witzke, 281-1520.

REFRIGERATOR, 26-cu. ft., water & ice, \$400; 1100-W microwave, \$75; dishwasher, \$100; 5-burner gas stove, \$250. Yopez, 505-934-2974.

'69-'72 CHEVY TRUCK PARTS, step-side bed, \$375; front clip, \$350; front bumper, \$30; passenger door, \$15. Aragon, 881-4795.

THREE-WHEEL SCOOTER, Go-Go Elite Traveller, 2011, excellent condition, compact design, easily maneuvers in tight spaces, w/basket/charger, \$500. Garcia, 917-2822, ask for Carol.

How to submit classified ads

DEADLINE: Friday noon before week of publication unless changed by holiday. Submit by one of these methods:

- EMAIL: Michelle Fleming (classads@sandia.gov)
- FAX: 844-0645
- MAIL: MS 1468 (Dept. 3651)
- INTERNAL WEB: On internal web homepage, click on News Center, then on Lab News link, and then on the very top of Lab News homepage "Submit a Classified Ad."

If you have questions, call Michelle at 844-4902.

Because of space constraints, ads will be printed on a first-come basis.

Ad rules

1. Limit 18 words, including last name and home phone (If you include a web or e-mail address, it will count as two or three words, depending on length of the address.)
2. Include organization and full name with the ad submission.
3. Submit ad in writing. No phone-ins.
4. Type or print ad legibly; use accepted abbreviations.
5. One ad per issue.
6. We will not run the same ad more than twice.
7. No "for rent" ads except for employees on temporary assignment.
8. No commercial ads.
9. For active Sandia members of the workforce, retired Sandians, and DOE employees.
10. Housing listed for sale is available without regard to race, creed, color, or national origin.
11. Work Wanted ads limited to student-aged children of employees.
12. We reserve the right not to publish any ad that may be considered offensive or in bad taste.

FREE LECTURE, feline hyperthyroidism, provided by Fabulous Felines, learn about your kitty's health, <http://fabulousfelines.org>. Stubblefield, 263-3468.

DIGITAL CAMERA, Nikon Coolpix S7000, 16-MP, optical image stabilization, 1080/60i high-definition video, long zoom, WiFi, like new, regular \$279, asking \$199. Kovarik, 918-3577.

PATIO UMBRELLA, 6-ft. diameter, \$60; electric heaters, 2, \$30 ea.; lounge chairs, 2, \$50 ea.; folding chairs, \$25 ea.; folding ladder, aluminum, \$85; water can, 7-gal., \$15, more. Garcia, 554-2690.

TRANSPORTATION

'06 HYUNDAI SONATA GLS, V6, 64K miles, \$5,750. Ruggirello, 505-221-7002.

'06 CHEVY SILVERADO 2500HD, LBZ Allison Duramax, upgrades, white, clean, see Craigslist ad, 121.6K miles, \$26,000. Smith, 505-907-8618.

'09 SMART CAR, loaded, 1 owner, 40K miles, excellent condition, \$8,000 OBO. Sturgeon, 505-975-6565.

'10 MINI COOPER CLUBMAN, 6-spd. manual, 47K miles, great shape, \$12,000 OBO. Maurer, 296-4869.

'96 TACOMA, extended, 2x4, salvage title (minor front-end damage), runs great, \$2,500 firm. Phillips, 505-218-0467.

'11 LEXUS ESC 350, chocolate mica color, 45K miles, \$19,000. Lehman, 294-5921.

'81 MERCEDES 380SLC, rare silver coupe, grey leather interior, fully loaded, 53.5K miles, good condition, \$9,500. Davis, 505-322-3915.

'87 TOYOTA CAMRY WAGON, 4-cyl., 5-spd. manual, 1 owner, 194K miles, rebuilt at 146K miles, \$1,200 OBO. Sears, 505-440-9959.

'71 GMC STEP-SIDE PICKUP, classic, 6-cyl., 3-spd., too much new stuff to list, \$4,500. Langwell, 382-3591.

RECREATION

'06 HARLEY ELECTRA GLIDE, black w/cam kit, new tires, Ultra trunk added, many extras, looks/runs/sounds great, \$10,900. Cocain, 281-2282.

'05 YAMAHA SILVERADO, 650cc, loaded w/many extras, 1,621 actual miles, \$3,500. Shelton, 450-9290.

INFLATABLE KAYAK, Sevylor River X K-1, pump, paddle, lightly used, class 4, 400-lb. capacity, \$200. Shaw, 505-980-7491.

'99 WANDERER 5TH WHEEL, 24-ft., 1 slide out, shower/bathtub, sleeps 6, 1 owner, excellent condition, \$7,500. Ortiz, 459-4744.

'02 TRIUMPH BONNEVILLE, 7.5K miles, excellent condition, w/misc. leathers, helmets, saddle bags, \$2,500. Holmes, 873-5255.

KID'S BIKES/TRIKE/SCOOTER, nice condition: specialized Hotrock 20, \$95; Hotrock 16, \$60; Kettler trike, \$60; Taxi, \$20. Richards, 331-1542.

REAL ESTATE

10.33 ACRES, San Pedro Creek Estates, P/cable, fantastic views of Sandia mountains, ski resort, plains, \$144,000. Fahrenhorst, 366-8020.

3-BDR. HOME, 2 baths, 1,980-sq. ft., Mossman, extremely desirable location, near Pennsylvania/Montgomery, recent updates, \$239,000. Fitzgerald, 323-9723.

WOODED MOUNTAIN LOT, near S14, off Raven Rd., homes on adjacent properties, only \$19,000. Gibson, 294-6831.

4-BDR. HOME, 4-car garage, close to Sandia, refrigerated air, paint, carpet, many upgrades, \$240,000. Rogulich, 459-6241.

WANTED

CAR SEAT, to transport grandchild, prefer convertible that supports different aged children, price negotiable. Kelly, 505-306-4365.

GREENHOUSE, old plastic tubs, vegetable garden equipment, got old but usable stuff you aren't using? Beggs, 505-414-2757.



Mileposts



New Mexico photos by Michelle Fleming

Recent Retirees



New Mexico photos by Michelle Fleming



Ruben Muniz 34 425



Ann Riley 33 10222



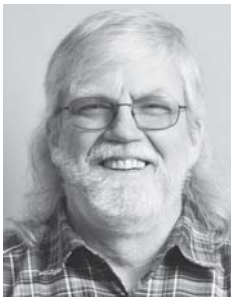
Marlene Uribe 32 2221



Michael Widmer 35 9542



Gary Laughlin 30 6020



Lyle Golightly 31 4847



Randall Cygan 30 6910



Ron Weagley 27 9538



Pam Catanach 26 3652



Linda Sager 17 8511



Up on the roof

Sandia tests whether homes are strong enough for solar

By Nancy Salem

America’s rooftops are ready for their close-up — their solar close-up, that is. Tests conducted by a Sandia-led research team indicate that the rooftops on Main Street USA are strong enough to support modern solar-energy systems in more cases than previously thought.

“There is a misperception in the building industry that existing residential rooftops lack the strength to carry the weight load of rooftop solar photovoltaic (PV) installations,” says structural engineer Steve Dwyer (6912). “Most existing well-built wooden rooftops can support PV system loads.”

Sandia took on the job of analyzing rooftop structural strength to address concerns raised in DOE’s Solar America Cities program. The agency named 25 US cities to promote adoption of solar technology at a comprehensive, local level through photovoltaics.

At least one city reported that the primary barrier to solar was the difficulty and cost of obtaining construction building permits for rooftop solar installations because of structural issues. “I couldn’t believe it was a problem,” says Steve, who led the Sandia test team. “Solar PV systems represent little additional weight and roofs are very strong.”

He says many code officials are not familiar with solar technologies and don’t have the training to evaluate how a solar PV system might affect roof structure, so they bring structural engineers into the permitting process, adding time and money for the system owner and the solar contractor. Engineering certification for the installation of solar PV modules on wood roofs is often denied because many structures are deemed not strong enough.

More load-bearing capacity

In two, first-of-their-kind studies (energy.sandia.gov/sandia-research-on-rooftop-structural-strength-gains-attention/) funded by DOE’s SunShot Initiative and conducted in partnership with the University of New Mexico (UNM), Sandia stressed wood rooftop structures to the



point of failure and compared the data with allowable loads identified in the International Residential Code and the National Design Standard.

They concluded the actual load-bearing capacity for residential rooftop structural systems is several times higher than the calculated values.

Sandia hopes the results will be used by engineers and code and permitting officials to make decisions about rooftop strength and solar PV applications, ultimately helping to support safe, cost-effective rooftop solar.

Visit energy.sandia.gov for more information on Sandia’s energy programs.

“Safety is a crucial factor in building codes and must be considered when there is any change to a structure,” Steve says. “Understanding how weight loads affect the structural integrity of a roof is important to homeowners, code officials, solar installers, and builders. These results provide a new tool and set of data for consideration in evaluating rooftops for solar PV installations.”

The roof acts as a whole

Steve says engineers doing rooftop structural analysis often calculate stresses on the basis of an individual beam, rafter, or truss. That approach assumes each component of the structure acts alone. “It fails to consider the rooftop system as a whole or consider the load-sharing or load redistribution effects of a roof system,” he says. “The result is a conservative analysis that does not accurately represent the roof’s ability to support a PV installation. It’s not a fair assessment.”

And he says engineering evaluations are not universally applied across cities and states. “Some do them and some don’t,” he says. “Local governments pick and choose what they accept. Not everybody uses the same method, so it can be difficult for solar installers and residents to know what to expect. All these issues have posed serious challenges to the solar industry.”

Steve says building codes won’t change, so the way to tackle the problem was to build some roofs, break them, and show the permitting community just how strong a roof is. Starting about three years ago, the team, which included UNM’s Walter Gerstle and several graduate students, built different roof sizes in a structural testing laboratory in a university lab.

“We did a lot of testing,” Steve says. “First we wanted to be sure we were on the right track. We thought, ‘OK, the engineers are not giving credit for load sharing, so we tested a two-by-four, broke it in half then nailed a piece of sheathing to it to see if it added strength. It did, 35 percent with nailing and 74 with gluing. We were on the right track.’”

They built scaled versions of roofs in different lengths with five rafters or trusses 8 to 20 feet long and applied a uniform load over the whole thing. “We used air as the load,” Steve says. “We built bladders of different sizes and used them to put pressure on top of the roof by filling them with air at up to 144 pounds per square foot. We broke every size rafter and the more commonly used trusses, five sets of each.”

On average, the rafter-based tests demonstrated a 330 percent excess load-bearing capacity compared to values computed in the National Design Standard. “This suggests that current rooftop structural evaluations are overly conservative in evaluating the ability of roofs to support additional loading from solar PV installations,” Steve says. “A well-built home that meets local building standards and has not been adversely modified or damaged should have enough load-bearing capacity to support a roof-mounted PV system.”

Getting behind solar



The DOE SunShot Initiative is a collaborative national effort that aggressively drives innovation to make solar energy fully cost-competitive with traditional energy sources before the end of the decade. Through SunShot, the Energy Department supports efforts by private companies, universities, and national laboratories to drive down the cost of solar electricity to \$0.06 per kilowatt-hour. Learn more at energy.gov/sunshot.

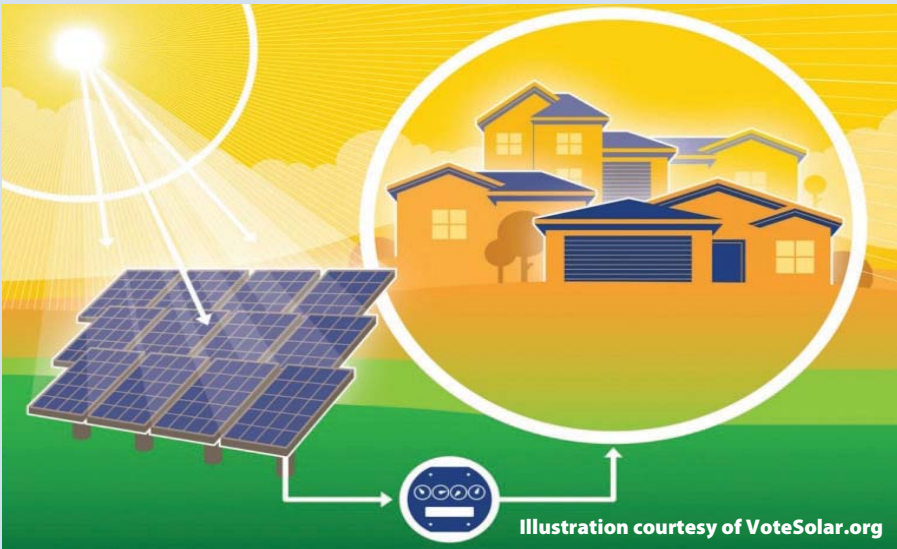


Illustration courtesy of VoteSolar.org